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Biological treatment: Optimization of biological rapid sand filters for drinking water production

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Drinking water production from groundwater will often require removal of several compounds such as ammonia, manganese, ferrous iron, methane, sulphides or natural organic matter (NOM). In rapid sand filters this may be mediated through microbial processes. Sometimes the filters unfortunately fail to meet the design criteria, and a deeper insight in the underlying processes would provide a necessary platform to solve the problems. Efficient removal of potential microbial substrates is essential for production of biostable water which is required when the produced drinking water is stored and distributed without a disinfection residual as e.g. in Denmark.

We have developed a toolbox including investigations of the presence of required microorganisms. To investigate the presence and density of various microbial fractions, qPCR-methods were established for quantification of ammonium oxidizing (AOB, AOA), nitrite oxidizing (NOB), iron oxidizing (IOB) and methane oxidizing (MeOB) microorganisms. In addition, pyrosequencing of the full microbiome of the sand filters revealed a high diversity, and especially the presence of a very large and dominating population of *Nitrospira* was surprizing.

Nitrification was particularly investigated in full scale filters, and lab-scale CST-columns incubated with depth specific samples of filter material allowed for investigation of the depth specific kinetics and maximum removal capacity. Additionally, pilot scale column experiments allowed for investigation of e.g. increased load of ammonium due to increased hydraulic load versus increased concentration, physical space in the filter material and its surface qualities. A safe operational windows in terms of load was identified during short term up-shifts in the ammonium load to the different columns. This showed the importance of the total load no matter the increase was due to hydraulic load or concentration.

Based on the obtained insight the functionality of the filters could be optimized. Addition of limiting micronutrients such as phosphorous or cupper (which specifically stimulating nitrification since cupper is an essential metal in the ammonium mono oxygenase) was able to increase nitrification rate, to overcome incomplete nitrification with accumulation of nitrite, and to reduce the startup time of the microbial processes in new filters.

This presentation provides an overview of a number of research projects on biological rapid sand filters conducted during the last 5 years.